PATENT SPECIFICATION (11) 1 399 067

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(21) Application No. 50238/73 (22) Filed 29 Oct. 1973
(31) Convention Application No. 123 933/72
(32) Filed 28 Oct. 1972 in
(33) Japan (JA)
(44) Complete Specification published 25 June 1975
(51) INT CL² G03B 11/00; G02B 5/22; G03B 9/06
(52) Index at acceptance G2J 22 28

(19)

(54) IMPROVEMENTS IN OR RELATING TO LIGHT-ATTENUATION DEVICES

(71) We, CANON KABUSHIKI KAISHA, a Japanese Company, of No. 30-2, 3-chome, Shimomaruko, Ohta-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to light-attenuating devices, and in particular to a light-attenuating device suitable for use as an adjustable diaphragm device for television cameras, photographic cameras and the like.

With recent developments in high sensitivity television image pick-up tubes, the possible range of brightnesses of scenes which can be photographed is extended from very bright to very dark ones. The objective lens system of a television camera having such an image pick-up tube must therefore be capable of controlling the light quantity falling on the tube over a very wide range, corresponding to the range of responsiveness of the image pick-up tube However, conventional television objective lens systems have light-attenuating devices incorporated therein in the form of a simple variable iris-type diaphragm, most of which are variable over the range from f/1.4 to f/32, which corresponds to a light-attenuation ratio of 1:1000, whereas a high sensitivity image pick-up tube may well require a light-attenuation ratio as large as several tens of times or even more than that of the light-attenuating device.

In order to overcome this difficulty, it is known to utilise a series of neutral density filters of different densities, which filters are selectively inserted into the optical path of the light-attenuating device as required. However, the selection of a suitable density of filter, and the interchanging thereof, have certain drawbacks that considerably reduce the overall performance of the television camera. In particular, the construction of the objective lens barrel is made very complicated.

The principal object of this invention is to provide a light-attenuating device capable of having a wide range of light-attenuation characteristics.

Accordingly, this invention provides a light-attenuating device comprising an adjustable mechanical diaphragm means the light-attenuation characteristics of which depend upon the aperture opening thereof, and at least one neutral density filter element optically aligned with the diaphragm means, the or each filter element including two regions of different densities, the first of which is central of the filter element, aligned on the optical axis of the diaphragm means, and has a substantially uniform density, whereas the second of which, being contiguous with the first region, has a density which reduces linearly outwardly from that of the first region, whereby the overall light-attenuation characteristics of the device depend upon the area of the aperture opening of the diaphragm means and upon the transmittance of the effective area of the or each filter element.

Preferably, the or each filter element is provided with a third region contiguous with and peripheral to the second region, the transmittance of the third region being substantially 100%.

In one preferred embodiment, the first and second regions are comprised of continuous-tone areas, although these regions may equally well be comprised of arranged neutral-colour dots, the density of which in the second region varies so as to reduce the density of the filter element outwardly. In either case, the filter element may be produced from a silver halide emulsion film, although for the latter type of filter, a printing method may advantageously be employed.

This invention also extends to an ob-

jective lens system whenever utilising a light-attenuating device according to this invention.

The invention further provides a method of producing a filter element for use in a light-attenuating device according to the invention, which method comprises focusing by projection with an imaging lens an object on the image plane of the lens, the object comprising a continuous-tone pattern, locating a light sensititive film in a plane normal to the optical axis of the imaging lens, said plane being displaced from and parallel to the image plane, exposing the light-sensitive film to obtain a negative, and then photographically processing the film to produce filter elements which have a central first region of uniform density and a second region of decreasing density, contiguous with the first region.

By way of example only, certain specific embodiments of the invention will now be described, reference being made to the accompanying drawings, in which:—

Figure 1 is a sectional view of a light-attenuating device adapted for use in a television cameras in accordance with the present invention;

Figure 2 is a front view of a neutral density filter incorporated in the light-attenuating device of Figure 1;

Figure 3 is a curve illustrating the variation in transmittance of the filter shown in Figure 2 plotted against radius of the filter;

Figure 4 is a schematic perspective view of an optical arrangement for producing the filter of Figure 2; and

Figure 5 is a front view of a filter having a modified arrangement of dots and having the same characteristics as those of the filter of Figure 2.

Referring now to Figure 1, a television objective lens system arranged in front of an image pick-up tube, indicated at 10, is schematically and fragmentally illustrated as including a compensator lens component 1 (other optical components such as a front lens assembly and a variator lens component of a zoom lens system being not shown), an aperture setting ring 2 rotatably mounted on a lens barrel 3, a fixed frame 4 mounted inside the lens barrel 3, diaphragm blades 5, pins 5_1 and 5_2 mounted on the diaphragm blades, pins 6_1 and 6_2 mounted on the aperture setting ring and engaged with slots provided in the dipahragm blades, a lens holding frame 7, a relay lens 8, and a neutral density filter 9 (or optical attenuator). The components 2, 3, 4, 5, 5_1, 5_2, 6_1, and 6_2 comprise a known form of iris diaphragm for regulating the aperture of the objective. The photo-electric converter surface of the television camera tube 10 is positioned at the focal plane of the zoom lens system.

Figure 2 is a front view of the filter 9, the density characteristics of which include three regions as diagrammatically illustrated in Figure 3. In the first central region R_1, which is centered on the optical axis of the objective, the density is substantially constant with radius and at a maximum for the filter (transmittance — about 20—25%) relative to the other regions, whereas in the annular second region R_2 outside of the central region R_1 the density decreases linearly with radius. The annular third region R_3 near the rim of the lens has no filtering action, i.e. is of substantially 100% transmittance.

Consideration will now be given to the operation of the light-attenuating device described above. In order to adjust the amount of light passing through the objective, the aperture setting ring 2 is rotated to the desired position to give the required aperture opening. This rotation may be effected manually or automatically, for example, by a servo motor. So long as the aperture opening defined by the iris diaphragm blades 5 is in such a range that the region R_3 of the filter 9 is excluded from the aperture opening, but the regions R_2 and R_1 are included therein, the amount of light passing through the aperture opening is varied as a function of the area of aperture opening and also the integrated density of the neutral density filter over the particular area. When the aperture is set to an opening sufficiently small to exclude the regions R_2 and R_3 of the filter, to include the region R_1, the amount of light passing through the aperture opening is dependent upon the particular aperture opening and the filter density, but is varied as a function of only the aperture opening, because the density of this central region of the filter is constant with radius. The reason why a central region of reasonable area and constant density is provided is based on the fact that the accuracy of control of the amount of light passing through the aperture opening is decreased with decrease in the area of aperture opening. The accuracy is in particular very low when the area of the aperture opening is so small as to accept light passing through the region R_1 only. If, instead of the filter having the form described above, the density were linearly decreased with radius from the centre (optical axis) in a similar manner to that in the region R_2, errors in aperture control would reach very large values — equivalent to the density variation in the central area of this alternative form of filter. Thus, in order substantially to reduce or eliminate such errors, the central region R_1 is arranged to have a uniform density, and to be of sufficiently large area so that the error in light-

attenuation at small apertures is dependent only upon the errors due to the control and action of the diaphragm blades 5.

It will be appreciated from the foregoing that the range of light-attenuation obtainable by the device of this invention is greatly extended as compared with an iris diaphragm alone. In practice, it is necessary only to operate the mechanical iris diaphragm device within the objective in the usual manner to obtain this extended range. If it is wished to fade-out light falling on the tube by gradually closing the diaphragm, the amount of light passing through the aperture opening can be decreased with a decrease in the area of he aperture opening and simultaneously the transmittance of the filter for light incident thereon is decreased with an increase in the integrated density of the filter, so that the amount of light emerging from the light-attenuating device of this invention is decreased as a function of the product of these two control parameters. Similarly, to fade-in, the amount of light passing through the aperture opening can be made to increase with an increase in the area of aperture opening, and simultaneously the transmittance at the filter is increased with an increase in the amount of light passing through the relatively low density portion of the filter so that the amount of light emerging from the overall light-attenuating device increases as the function of the product of these two control parameters.

Various modifications may be made to the above-described characteristics of the neutral density filter as well as to the light-attenuating device incorporating the filter, and yet still lie within the scope of this invention, as defined by the claims. For example, the filter (or other optical attenuator) may be arranged in front of the iris diaphragm, or two filters (or other optical attenuators) may be employed one each side of the iris diaphragm. From the standpoint of restricting the light loss of the device at the fully open aperture position to be as small a value as possible, it is preferred that the characteristics and size of the optical attenuator are determined by taking into account the overall lens aperture and the uniform gradient of light-attenuation.

In Figure 4, there is shown diagrammatically an optical system for making the filter 9 of the device shown in Figure 1. In this arrangement, an original 11, comprising a transparency carrying a circular solid pattern 11_1 (i.e. a circular continuous-tone pattern) centered on the optical axis system is projected by a light source (not shown) through an imaging lens 12 on to a photosensitive silver halide emulsion film positioned just in front of the focal plane 13 of the lens 12. In this way the image of the circular pattern on the film 14 is vignetted so that the intensity of the incident light upon the film is progressively varied with radius outwardly from the region which is centered at the optical axis, while in that central region, the intensity of incident light is almost constant with radius. After a suitable exposure has been made using an appropriate shutter mechanism (not shown), the exposed film is developed and fixed in a known manner to produce a negative film from which neutral density filters having the characteristics shown in Figure 3 can be produced — for example by a photographic contact printing process.

An alternative form of suitable neutral density filter is shown in Figure 5, and comprises a plurality of neutral colour dots, the density of which is varied radially. In this case, any appropriate printing technique may be utilised to produce with ease the filter.

As mentioned above, an objective lens having a light-attenuating device according to this invention is capable of continuous light-attenuation over a very wide range simply by adjusting the aperture opening of a mechanical diaphragm. In fact, the radio of light-attenuation can reach several tens of times that of a mechanical diaphragm alone, and is of particular use for television cameras provided with image pick-up tubes having high sensitivity photoelectric converter surfaces. The device is also very useful for photographic and cinematographic cameras associated with high sensitivity photographic film. Thus, it is possible to effect a correct exposure with high accuracy over a wide range of brightness of subjects to be photographed.

WHAT WE CLAIM IS:—

1. A light-attenuating device comprising an adjustable mechanical diaphragm means the light-attenuation characteristics of which depend upon the aperture opening thereof, and at least one neutral density filter element optically aligned with the diaphragm means, the or each filter element including two regions of different densities, the first of which is central of the filter element, aligned on the optical axis of the diaphragm means, and has a substantially uniform density, whereas the second of which, being contiguous with the first region, has a density which reduces linearly outwardly from that of the first region, whereby the overall light-attenuation characteristics of the device depend upon the area of the aperture opening of the diaphragm means and upon the transmittance of the effective area of the or each filter element.

2. A light-attenuating device as claimed in claim 1, wherein the or each filter element has a third region contiguous with and

peripheral to the second region, the third region having a transmittance of substantially 100%.

3. A light-attenuating device as claimed in either of the preceding claims, wherein the first and second regions are continuous-tone areas.

4. A light-attenuating device as claimed in claim 1 or claim 2, wherein the first and second regions are formed by arranged neutral-colour dots, the density of which is varied to give the regions the desired characteristics.

5. A light-attenuating device as claimed in any of the preceding claims wherein the or each filter element is made from a silver halide emulsion film.

6. A light-attenuating device substantially as hereinbefore described with reference to and as illustrated in the Figures of the accompanying drawings.

7. An objective lens system whenever incorporating a light-attenuating device according to any of the preceding claims.

8. A method of producing a filter element for use in a light-attenuating device according to any of claims 1 to 6, which method comprises focussing by projection with an imaging lens an object on the image plane of the lens, the object comprising a continuous-tone pattern, locating a light sensitive film in a plane normal to the optical axis of the imaging lens, said plane being displaced from and parallel to the image plane, exposing the light-sensitive film to obtain a negative, and then photographically processing the film to produce filter elements which have a central first region of uniform density and a second region of decreasing density, contiguous with the first region.

9. A method according to claim 8, wherein the object comprises a transparency having a solid, continuous-tone circular area thereon.

10. A method of producing neutral density filter elements substantially as hereinbefore described, with reference to and as illustrated in Figure 4 of the accompanying drawings.

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Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1975.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1399067 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

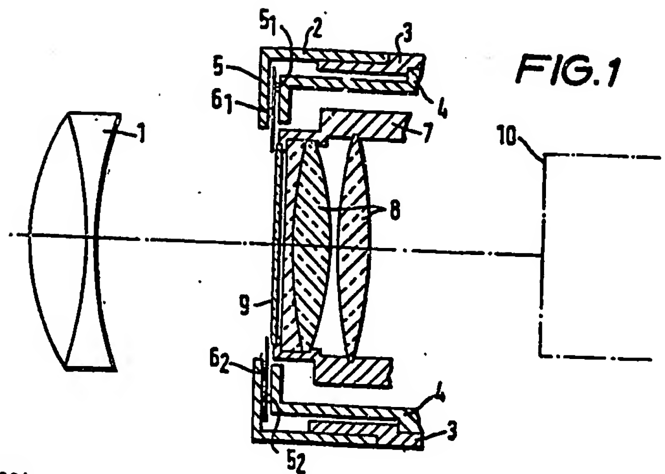


FIG.1

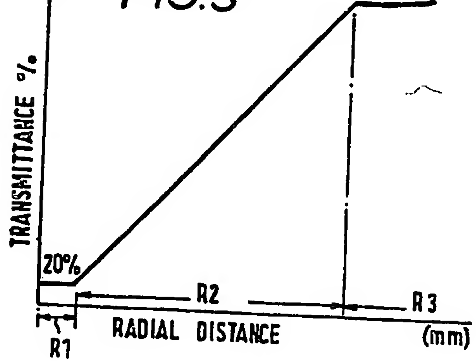
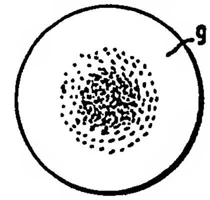


FIG.3

FIG. 2


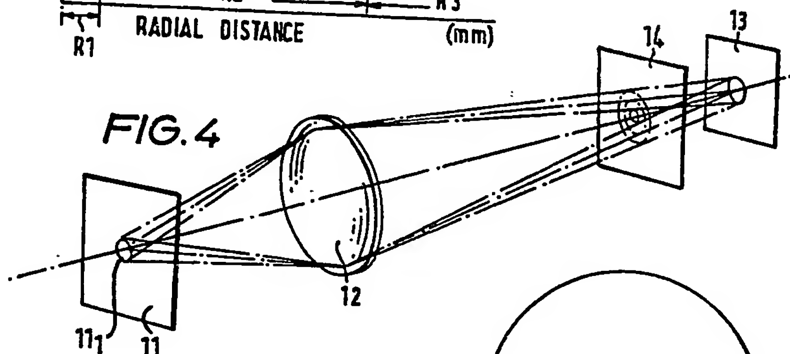


FIG.4

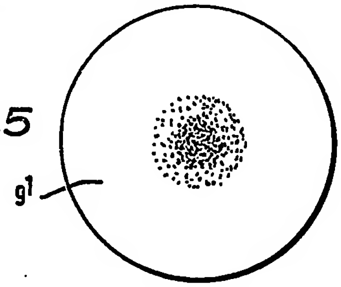


FIG.5